

Performance Analysis of BUNSD-LMA

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Abstract

The IETF is developed Network Mobility Basic Support (NEMO BSP) to support session continuity and reachability to the Mobile Network Nodes (MNNs) as one unit while they move. While NEMO move and attached to different networks, it needs to register the MNNs. This function of registration decreases the performance of NEMO. NEMO BSP suffers from some challenges. The most important of these challenges are route optimization, seamless mobility, handover latency and registration time. Binding Update No Sense Drop (BUNSD) Binding Cache Entry (BCE) in Local Mobility Anchor (LMA) is proposed to find a possible solution to MNNs. MNNs that are roaming in a Proxy Mobile IPv6 (PMIPv6) domain to perform seamless mobility while they are maintaining their session continuity through mobile router (MR). In this paper, BUNSD-LMA is analyzed mathematically with NEMO BS based on handover latency, total packet delivery delay cost, and throughput time during handoff. The analytical result shows that the BUNSD-LMA had better performance in term of handover, and registrations of MNNs. As a result the total packet loss is decreased and seamless mobility of MNNs enhanced compared to NEMO BS benchmarks.

Keywords: NEMO, PMIPv6, BUNSD, MR, MAG, LMA.

1. Introduction

Today mobile devices have become an essential part of our daily life. The mobile IP (MIP) protocol enables host mobility support. With the fast increase in wireless network technology, MIP version six (MIPv6) has become very important to researchers to develop a powerful mobile devices. These mobiles run mobile applications to get access to multimedia and data services over broadband wireless connections based on IPv6 [1].

The key benefit of Mobile IPv6 is that even though the mobile node changes its domains and addresses during handover, the existing connections through which the mobile node is communicating can be maintained. To do this, connections to mobile nodes

are configured with specific addresses. These addresses are always assigned to the mobile nodes interfaces which generated from their link layer addresses. Besides, the mobile nodes are always reachable through it [2].

Host mobility management is the method by which the mobility of every mobile node is managed independently. the host mobility it is not sufficient for true mobility due to handoff latency and relatively huge exchange of messages between MN and home agent (HA). In [3] and [4] the performance of host mobility was enhanced by means of localized mobility domain (LMD). LMD helped the HA closer to MN to get faster signal exchange. Network mobility management is the method by which the mobility of group of mobile nodes is managed together. To enable network mobility, the Internet Engineering Task Force (IETF) has developed Network Mobility Basic Support Protocol (NEMO BSP) [5]. The NEMO consists MNN and MR. The MNN include Local Mobile Node (LMN), Fixed Mobile Node (FMN) such as cameras, sensors, and Visiting Mobile Node (VMN) such as customers with PDAs, smart phone and laptop. MNN uses MR local services to connect to the internet.

The NEMO changes its point of attachment to network infrastructure using mobile router (MR) as one unit. The MR is responsible for handover function on behalf of mobile network nodes MNNs. In addition, it negotiates the mobile network prefix MNP with the HA that resides in the home mobile network. The detail is shown in figure.1.

One of the important issues of Network mobility scheme is the handoff management. Handoff is, how to keep services continue to internet without interruption. When Mobile Router (MR) changes its point of attachment to another network known as Visited network, it needs to update its home agent (HA) with the new location. The MR acquires Care-of-Address (CoA) from visited network. Then it sends binding update message to its HA. These messages negatively affect the performance of NEMO BSP.

Mobility management in NEMO differs from host mobility in some aspects and agrees in others. Regarding handoff, in host mobility every MN performs handoff signalling every time it changes its point of attachment. But, in network mobility MR carry out handoff on behalf of MNs. On the other hand, in both schemas the registration and location update is done by each MN. Accordingly, each MN sends BU and receives BA. Handoff and registration followed by configuration of tunnel. The schemas differ in the way they establish the

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tunnel. Host mobility the tunnel configured between home agent and mobile nodes care of address (CoA). While, in NEMO all traffic is forward through tunnel between the HA and mobile router CoA.

NEMO BSP has some limitations such as handover delay and power consumption compared to network mobility management schemes. Most of the previous studies focus on these problems [6] [7] [4] [8]. However, more work is needed to support real time applications.

BUNSD-LMA was proposed to allow MNNs that are roaming in a NEMO domain to perform seamless mobility. It integrates PMIPv6 with NEMO BSP. In addition to, it extends binding update message format. The extension is used to register the MNNs prefix in advance with short time. The advanced registration is enhanced the seamless mobility of the schemas [9] [10].

The objective of this work is to analyze the performance of BUNSD-LMA. An analytical cost model is developed. The model takes into account transmission cost, bandwidth cost, propagation cost, and processing cost. Based on the analytical the performance of BUNSD-LMA is evaluated and bench marked with NEMO BSP and EfNEMO [11] standards.

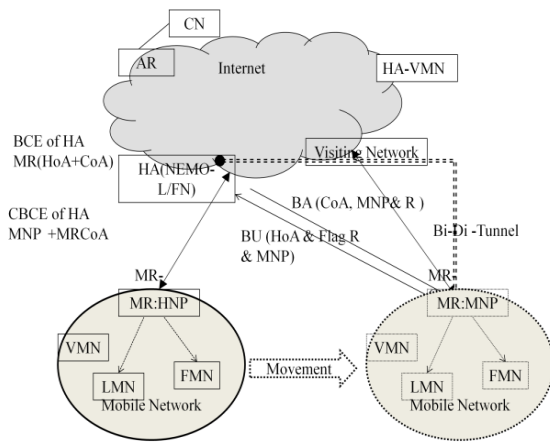


Fig. 1. Operation of the NEMO Network

2. Proposed Architecture Binding Update No Sense Drop BCE in LMA (BUNSD-LMA)

In this section, the network topology of the proposed BUNSD-LMA scheme and its elements is described. After that, the scenario of solving the problem of packet loss and handover delay is explained. This is based on integration of PMIPv6 with NEMO BS. Then, a pre-registration of MNP (HNP) in advance with short time update in binding update extensions message format is used. Figure 2 shows more details.

NEMO BS changes its point of attachment to network infrastructure using one mobile router (MR). The NEMO consists of LMN and FMN (cameras, sensors) and visiting mobile nodes VMN (customers with PDAs, smart phone and laptop) to use their local services to connect to the internet. The mobile router is responsible for triggering

the handover on behalf of MNNs as one unit. In addition to that, generate the mobile network prefix MNP from the home agent (HA) that resides in the home mobile network. This process is done by using binding update BU and Binding Acknowledgement BA. The last mobile network prefix is generated from its home network sent back by binding acknowledgement BA to the MR. This time the MR configures its permanent HoA, and MNNs get their IPv6 addresses from the advertised MNP. However, the VMNs configure it as CoAs because its home agents outside the mobile home network [5].

The MAG in BUNSD-LMA is used to implement the mobility function on behalf of MNNs. To register these MNNs it uses extended Binding Update message format. To register the MNNs, MNP prefix is passed from previous MAG. MAG register the MNP of MNNs on behalf of MR with flag G set to one and the MNP time set to short. This time is valid for one session. When the MR finishes the configuration of CoA, it maintains a bi-directional tunnel between HA and MR. The tunnel is used to forward all packets sent from/to MNNs and the correspondent node CN. The CN is any device that communicates with MNNs. If LMA Senses any messages sent to/from MNNs it registers that and send fast Binding Acknowledgement FBA message to PMAG to drop the bonded Cache Entry. However if LMA doesnot Sense any package sent from any of MNNs it Drops the BCE of LMA. Figure 2 shows more details [10].

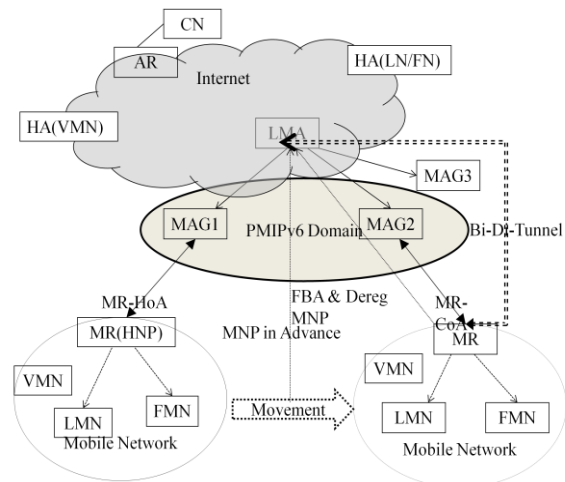


Fig. 2. Proposed BUNSD-LMA Architecture

							OPType	OPLen
A	H	R	D	G	R S V E	Prefix	Sequence No	
					D	Len		
Live time								

Fig. 3. BUNSD-LMA Binding Update Message Format.

- a. Flag G: When set to 1 it indicates that the MR needs to register its CoA and MNP in sub-option with HA. In this case the life time must be short.

- b. HA Operation: While HA intercepts any packets destined to or from MNNs, the HA must verify the HA-BCE, if flag G=1 it must update the binding path life time and delete the flag G.

3. Operation of the proposed architecture

In this section, the operation of BUNSD-LMA is explained. BU and BA message formats are extended with the MNP option as shown in figure 6 in order to register a mobile network prefix of MNNs to the home agent of mobile network (HA=LMA) in BUNSD-LMA. While MAG1 in PMIPv6 domain senses movement of MR to MAG2, this event is detected by sending router solicitation (RS) containing the MNP of MNNs. MNP is delegated to support MNNs (FMN, LMN, and VMN). The MAG1 checks its authorization to use BUNSD-LMA mobility management services. Then, MAG1 exchanges signaling with HA on behalf of MR. The BUNSD-LMA authorizes the MR and responds by a router advertisement containing the new MAG2 prefix. This prefix is forwarded to MR by MAG1. Then MR configures the CoA address from HNP and tunnel set up between MAG2 and LMA. While NEMO changes its point of attachment, every MNN sends BU and receives BA through the established tunnel between the LMA and MAG2. The PMIPv6 domain registers the MNNs of NEMO based on HNP obtained from LMA. However, all mobile nodes in the movement of NEMO are assigned HNP as MNP delegated by the mobile router (MR) [9]. The details of signaling diagram are shown in figure 7.

Figure 6 shows the details of signaling diagram while MR initiates the handover to MAG3. The MAG2 sends PBU to LMA with HNP flag to pre-register MNNs bonded with MAG2 and MNP=HNP to be bonded with MAG3 in LMA in advance. In this case, the HNP prefix life time must be short. Then, if LMA (HA) intercepts any packet delivered to MNNs, the LMA must update the BCE of LMA with valid lifetime and send fast deregistration message FPA to MAG2. Then, MAG2 deletes the same MNP bonded in its cache. Otherwise, the bonded MNP prefix in LMA cache must be dropped (see figure 8). However, in the second movement to MAG3, all MNNs are registered with one PBU and PBA to LMA. This binding update has extended message format option flag set to 1. This leads to less bandwidth consumption and low latency. In addition, the handover of the MR takes two signals to join MAG3. However, the result is an enhanced seamless mobility of MNNs compared to NEMO BS benchmarks.

4. Performance Analysis

In this section, we analyze our scheme performance using mathematical and Matlab for results.

4.1 Handover Managements

In mobility management, during the handover process the MNNs cannot send or receive any packet from the CNs. For this, IPv6 handover processes can be classified into

Link layer handoff (Layer two delays) which is the process time from MR to find and associate with a new Access Point. Second the IPv6 network layer handoff (layer three delays). In which are Router Discovery and assignment of CoA. This can be done by sending a Router Solicitation (RS) and receiving a Router Advertisement (RA) from a new Access Router. Then the assignment of CoA required Duplicate Address Detection (DAD) process. Third is home agent registration latency (layer three delays). The process of sending a BU from MR or MN to its HA and receiving a binding acknowledgement BA from HA.

$$\text{Handover delay} = \text{link layer} + \text{network layer} = L2 + L3$$

$$L2 = T_{\text{scan}} + T_{\text{aaa}} + T_{\text{re-ass}} \quad (1)$$

$$L3 = T_{\text{CONF}} + T_{\text{DAD}} + T_{\text{REG}} + T_{\text{MD}} \quad (2)$$

$$T_{\text{MD}} = T_{\text{RS}} + T_{\text{RA}} \quad (3)$$

$$T_{\text{RS}} = T_{\text{RA}} = \frac{1}{2} \frac{(\text{MinRTRInterval} + \text{MAXRTRInterval})}{2}$$

$$T_{\text{REG}} = T_{\text{BU}} + T_{\text{BA}} \quad (4)$$

4.1.1 Handover latency of PMIPv6

Firstly, PMIPv6 handover latency in our study is analyzed. assumed that MNNs and Mobile Router first attached to PMIPv6 domain to do mobility function on behalf of Mobile Router. After finishing handover process, the BUNSD-LMA can perform the full registration of MNNs. Figure 6 describes the signaling diagram of PMIPv6 registration scenario.

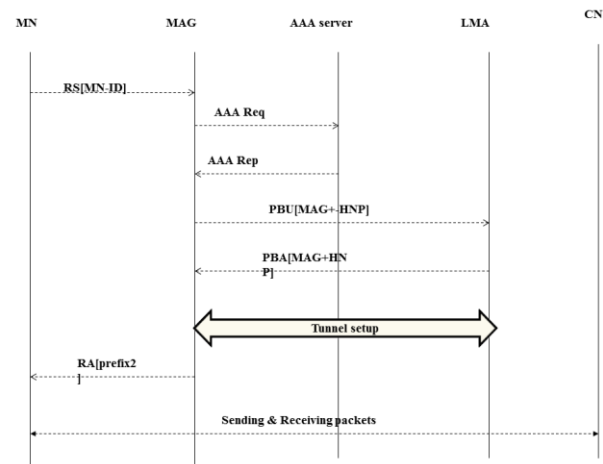


Fig. 4. Handover latency of PMIPv6

The PMIPv6 latency is composed of link layer and network layer, $T_{\text{PMIPv6}} = L2 + L3$

Thus, the latency of PMIPv6 when performing a handover from MAG to another MAG is calculated through the following formula.

$$T_{PMIPv6} = N_{MNN} \times (T_{scan} + T_{aaa} + T_{re-ass} + T_{CONF} + T_{DAD} + T_{RS} + T_{RA} + T_{PBU} + T_{PBA})$$

The N_{MNN} is the Total number of mobile network nodes that updating their locations compared to our proposed schema.

In PMIPv6, the MN uses the same address in all movements. However, no need for DAD and CoA Configuration due to PMIPv6 specification because the MN is already in proxy domain [12].

Reference to figure 4.1 RS = RA

By applying (1), (2), (3), and (4)

$$T_{PMIPv6} = N_{MNN} \times (T_{scan} + T_{aaa} + T_{re-ass} + 2T_{RS} + T_{PBU} + T_{PBA}) \quad (5)$$

4.1.2 Handover latency of NEMO BS

The handover latency of NEMO BS composed of Layer three, layer two, and registrations of all mobile network nodes.

$$T_{NEMO} = L2 + L3 + N_{MNN} \times (T_{BU} + T_{BA})$$

Where N_{MNN} are the number of mobile network nodes that updating their locations.

By applying (1), (2), (3), and (4) and RS=RA in fig 4.2

$$T_{NEMO} = T_{scan} + T_{aaa} + T_{re-ass} + T_{CONF} + T_{DAD} + 2T_{RS} + N_{MNN} \times (T_{BU} + T_{BA}) \quad (6)$$

4.1.3 Handover latency of EfNEMO: Bench Mark.

EFNEMO extend fNEMO to perform HA registration in advance to register the NCoA. This technique is used to send all packets between MNN and CN through path connect between NAR and PAR. However, using TBU embedded with FBU message to mitigate the burden on tunnel and reduce Handover Latency [11].

$$T_{EfNEMO} = T_{scan} + T_{aaa} + T_{re-ass} + T_{CONF} + T_{new} + T_{Fast} + T_{DAD} + 2T_{RS} + N_{MNN} \times (T_{BU} + T_{BA}) \quad (7)$$

Where TFast is the required time for additional signal before L2 handover occurred. Tnew is delay time of informing attachments to NAR. Handover latency of NEMO BS using PMIPv6.

In P-NEMO [13] the handover performance of NEMO is supported by PMIPv6 domain by using MAG and LMA. However, the registration is done using PBU and PBA to register MNNs. To calculate the latency of whole scenario same as above formula, we use T_{NEMO} Integrated with PMIPv6 = L2 + L3

The PMIPv6 do the mobility functions on behalf of MR. However, any MNN send binding update and binding acknowledgement to complete their registration. And RS=RA

By applying (1), (2), (3), and (4)

$$T_{NEMO+PMIPv6} = T_{scan} + T_{aaa} + T_{re-ass} + 2T_{RS} + N_{MNN} \times (T_{PBU} + T_{PBA}) \quad (8)$$

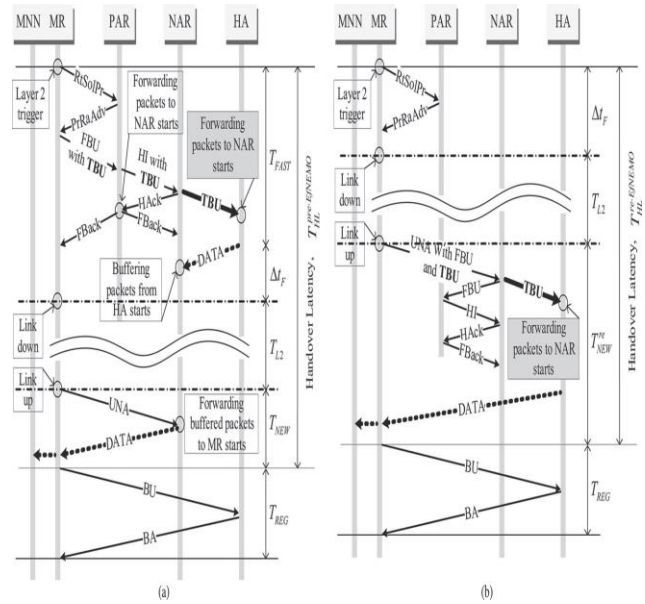


Fig. 5. The Handover operations and timing diagrams in EfNEMO [11].

4.1.4 Handover latency of BUNSD-LMA

The handover latency of BUNSD-LMA is time between the movement of MR triggering layer-2 to move to another network and the time that MNNs receive first message from CN. Hence, the latency is consist of link layer and network layer the formula is calculated as $T_{BUNSD-LMA} = L2 + L3$

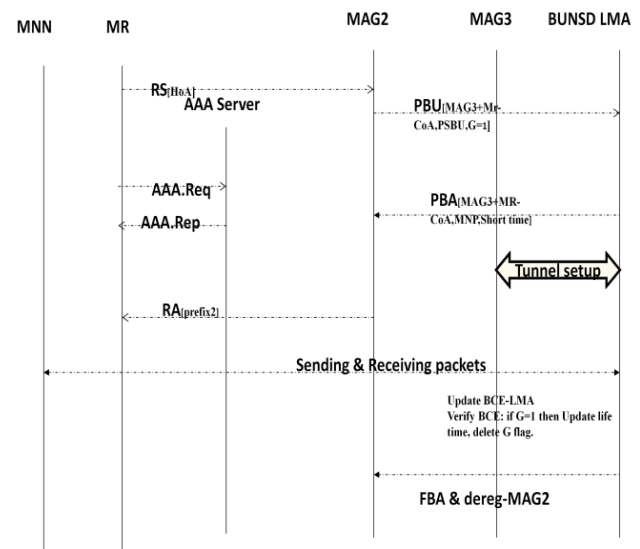


Fig. 6. BUNSD-LMA signalling diagram

Here also in PMIPv6, the MNN uses the same address in all movements. However, it is not needed DAD and CoA Configuration due to PMIPv6 specification because the MN is already in proxy domain [12]. And reference to fig 4.4 RS=RA

By applying (1), (2), (3), and (4)

$$T_{\text{BUNSD-LMA}} = T_{\text{scan}} + T_{\text{aaa}} + T_{\text{re-ass}} + 2T_{\text{RS}} + T_{\text{EPBU}} \quad (9)$$

BUNSD-LMA bind the N_{MNN} as Group using Extended Proxy binding update message format option (EPBA). However this message did not affect the equation because, it is included in BA message format design.

The TBA is received as TFBA after first packet intercepted through HA (LMA). This time can be omitted because, it does not affect handover.

4.2 Packet Delay

The delay of packet is composed of processing delay, transmission delay and propagation delay. This can be expressed in equation (10).

$$\text{Packet delay} = T_{\text{trans}} + T_{\text{prop}} + T_{\text{proc}} \quad (10)$$

Where T_{trans} the delay time for packet transmission, T_{prop} is the time for signal propagate from the source to destination device and T_{proc} is time for processing packet.

$T_{\text{trans}} = \text{packet size} / \text{link bandwidth}$

$$\text{Wireless delay} = T_{\text{proc}} + P_{\text{size}} / B_{\text{wl}} + L_{\text{wl}} \quad (11)$$

$$\text{Wired link delay} = (T_{\text{proc}} + P_{\text{size}} / B_{\text{w}} + L_{\text{w}}) \times N_{\text{hop}} \quad (12)$$

The wired link is stable and we assume that wired link without transmission failure. However, the packets transmissions are expected in wireless. The Probability failure P_f for packet loss in every movement of MNN in the wireless link is calculated as follows [11].

$$P_f = f(P) = \sum_{N_f}^{\infty} N_f \text{Prop}(N_f \text{ failure and } 1 \text{ success}) = \frac{P_f}{1-P_f} = \left(\frac{P_f}{1-P_f} \right)$$

$$T_{\text{BA}} = (T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{wl}}} + L_{\text{wl}}) \times \left(\frac{P_f}{1-P_f} \right) + (T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{w}}} + L_{\text{w}}) \times N_{\text{hop}} \quad (13)$$

$$T_{\text{BA}} = N_{\text{hop}} \left(L_{\text{w}} + T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{w}}} \right) + \frac{P_f (L_{\text{wl}} + T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{wl}}})}{1-P_f} \quad \text{Where } P_f \neq 1 \text{ and } B_{\text{wl}} \neq 0 \text{ and } B_{\text{w}} \neq 0$$

Where $H_{\text{MR-AR}} = N_{\text{wl}}$ and $H_{\text{AR-HA-MR}} = N_{\text{w}}$, $T_{\text{BA}} = T_{\text{BU}}$ in different packet size.

$$\text{RS}=\text{RA}=\text{TRS} (\text{MN/MR,AR/MAG})$$

$$T_{\text{RS}} = T_{\text{RA}} = (T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{wl}}} + L_{\text{wl}}) \times \left(\frac{P_f}{1-P_f} \right)$$

$$T_{\text{RS}} = \frac{P_f (L_{\text{wl}} + T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{wl}}})}{1-P_f} \quad \text{Where } P_f \neq 1 \text{ and } B_{\text{wl}} \neq 0$$

4.2.1 Packet Delivery cost PMIPv6

$$P_{\text{c}}(\text{PMIPv6}) = (P_{\text{c}}(\text{MAG}) + P_{\text{c}}(\text{LMA}) + T_{\text{tunnel}}) \times N_{\text{MNN}}$$

By applying 11 and 12

$$P_{\text{c}}(\text{PMIPv6}) = ((T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{wl}}} + L_{\text{wl}}) \times \left(\frac{P_f}{1-P_f} \right) + (T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{w}}} + L_{\text{w}}) \times N_{\text{hop}} + T_{\text{tunnel}}) \times N_{\text{MNN}}$$

$$P_{\text{c}}(\text{PMIPv6}) = N_{\text{MNN}} \left(N_{\text{hop}} \left(L_{\text{w}} + T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{w}}} \right) + \frac{P_f (L_{\text{wl}} + T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{wl}}})}{1-P_f} + T_{\text{tunnel}} \right)$$

Where $P_f \neq 1$ and $B_{\text{wl}} \neq 0$ and $B_{\text{w}} \neq 0$ (14)

$$T_{\text{PBA}} = (T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{wl}}} + L_{\text{wl}}) \times \left(\frac{P_f}{1-P_f} \right) \times N_{\text{wl}}$$

$$T_{\text{PBA}} = \frac{P_f N_{\text{wl}} (L_{\text{wl}} + T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{wl}}})}{1-P_f} \quad \text{Where } P_f \neq 1 \text{ and } B_{\text{wl}} \neq 0$$

4.2.2 Packet delivery cost of FMIPv6

The packet is to be forward and buffered in FMIPv6 [14].

$$P_{\text{c}}(\text{FMIPv6}) = T_{\text{proc}} \times (\text{handover delay } L2/L3) + \text{MIP (BU, BA)}$$

$$P_{\text{c}}(\text{FMIPv6}) = N_{\text{MNN}} \times (C_{\text{forwarding}} + C_{\text{buffering}})$$

$$P_{\text{c}}(\text{FMIPv6}) = T_{\text{proc}} \times (2 T_{\text{RA-HA}} + P_{\text{HA}}) + (T_{\text{AR-AR}} + T_{\text{NAR}}) \quad (16)$$

4.2.3 Packet Delivery cost NEMO BS

$$P_{\text{c}}(\text{NEMO}) = (P_{\text{c}}(\text{MR}) + P_{\text{c}}(\text{HA}_{\text{MR}}) + T_{\text{tunnel}}) \times N_{\text{MNN}}$$

By applying 11 and 12

$$P_{\text{c}}(\text{NEMO}) = ((T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{wl}}} + L_{\text{wl}}) \times \left(\frac{P_f}{1-P_f} \right) + (T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{w}}} + L_{\text{w}}) \times N_{\text{hop}} + T_{\text{tunnel}}) \times N_{\text{MNN}}$$

$$P_{\text{c}}(\text{NEMO}) = N_{\text{MNN}} \left(N_{\text{hop}} \left(L_{\text{w}} + T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{w}}} \right) + \frac{P_f (L_{\text{wl}} + T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{wl}}})}{1-P_f} + T_{\text{tunnel}} \right)$$

Where $P_f \neq 1$ and $B_{\text{wl}} \neq 0$ and $B_{\text{w}} \neq 0$ (17)

$$T_{\text{BA}} = (T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{wl}}} + L_{\text{wl}}) \times \left(\frac{P_f}{1-P_f} \right) \times N_{\text{wl}} + (T_{\text{proc}} + \frac{P_{\text{size}}}{B_{\text{w}}} + L_{\text{w}}) \times N_{\text{hop}}$$

$$T_{BA} = \frac{P_f N_{wl} \left(L_{wl} + T_{Proc} + \frac{P_{size}}{B_{wl}} \right)}{1 - P_f} + N_{hop} \left(L_{wl} + T_{Proc} + \frac{P_{size}}{B_{wl}} \right) \quad \text{Where } P_f \neq 1 \text{ and } B_{wl} \neq 0 \text{ and } B_w \neq 0$$

4.2.4 Packet delay cost of EfNEMO: Bench Mark

$$P_c(\text{EfNEMO}) = (P_c(\text{MR}) + P_c(\text{FMIPv6}) + T_{\text{tunnel}}) \times N_{MNN}$$

By applying 11 and 12, and 16

$$P_c(\text{EfNEMO}) = ((T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl}) \times (\frac{P_f}{1 - P_f}) + 2 \times ((T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl}) \times (\frac{P_f}{1 - P_f}) + (T_{Proc} + \frac{P_{size}}{B_w} + L_w) \times N_{hop}) + T_{\text{tunnel}}) \times N_{MNN}$$

$$P_c(\text{EfNEMO}) = N_{MNN} \left(N_{hop} \left(L_{wl} + T_{Proc} + \frac{P_{size}}{B_{wl}} \right) + \frac{4P_f \left(L_{wl} + T_{Proc} + \frac{P_{size}}{B_{wl}} \right) + T_{\text{tunnel}}}{1 - P_f} \right) \quad (18)$$

4.2.5 Packet Delivery cost NEMO BS + PMIPv6

$$P_c(\text{NEMO} + \text{PMIPv6}) = (P_c(\text{MR}) + P_c(\text{PMIPv6}) + T_{\text{tunnel}}) \times N_{MNN}$$

By applying 11 and 12, and 14

$$P_c(\text{NEMO} + \text{PMIPv6}) = ((T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl}) \times (\frac{P_f}{1 - P_f}) + ((T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl}) \times (\frac{P_f}{1 - P_f}) + (T_{Proc} + \frac{P_{size}}{B_w} + L_w) \times N_{hop} + T_{\text{tunnel}}) \times N_{MNN} \quad (19)$$

$$P_c(\text{NEMO} + \text{PMIPv6}) = N_{MNN} \left(N_{hop} \left(L_{wl} + T_{Proc} + \frac{P_{size}}{B_w} \right) + \frac{2P_f \left(L_{wl} + T_{Proc} + \frac{P_{size}}{B_{wl}} \right) + 2T_{\text{tunnel}}}{1 - P_f} \right) \quad (19)$$

Here the binding update is performing by PMIPv6 for this we use equation [].

$$T_{PBA} = (T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl}) \times (\frac{P_f}{1 - P_f}) \times N_{wl}$$

$$T_{PBA} = \frac{P_f N_{wl} \left(L_{wl} + T_{Proc} + \frac{P_{size}}{B_{wl}} \right)}{1 - P_f} \quad \text{Where } P_f \neq 1 \text{ and } B_{wl} \neq 0$$

4.2.6 Packet Delivery cost BUNSD-LMA

$$P_c(\text{BUNSD-LMA}) = (P_c(\text{MR}) + P_c(\text{PMIPv6})) \times N_{MNN}$$

By applying 11 and 12, and 14

$$P_c(\text{BUNSD-LMA}) = ((T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl}) \times (\frac{P_f}{1 - P_f}) + ((T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl}) \times (\frac{P_f}{1 - P_f}) + (T_{Proc} + \frac{P_{size}}{B_{wl}} + L_w) \times N_{hop} + T_{\text{tunnel}}) \times N_{MNN} \quad (20)$$

$$P_c(\text{BUNSD-LMA}) = N_{MNN} \left(N_{hop} \left(L_{wl} + T_{Proc} + \frac{P_{size}}{B_{wl}} \right) + \frac{2P_f \left(L_{wl} + T_{Proc} + \frac{P_{size}}{B_{wl}} \right) + T_{\text{tunnel}}}{1 - P_f} \right) \quad \text{Where } P_f \neq 1 \text{ and } B_{wl} \neq 0 \quad (20)$$

The binding update of BUNSD-LMA is performing by PMIPv6 for this we use equation [].

$$T_{PBA} = (T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl}) \times (\frac{P_f}{1 - P_f}) \times N_{wl}$$

$$T_{PBA} = \frac{P_f N_{wl} \left(L_{wl} + T_{Proc} + \frac{P_{size}}{B_{wl}} \right)}{1 - P_f} \quad \text{Where } P_f \neq 1 \text{ and } B_{wl} \neq 0$$

4.3 Total Cost

In this section we analysis of BUNSD-LMA related to PMIPv6 and NEMO BS schemes. The total cost (TC) is composed of handover latency cost and packet delay cost. We calculate the cost of mobile network nodes in the three schemes for comparative purpose.

4.3.1 Total Cost of PMIPv6

Following is the total cost of PMIPv6 by applying equation (5) and (14).

$$TC_{\text{PMIPv6}} = N_{MNN} \times (T_{\text{scan}} + T_{\text{aaa}} + T_{\text{re-ass}} + T_{\text{CONF}} + T_{\text{DAD}} + T_{\text{RS}} + T_{\text{RA}} + T_{\text{BU}} + T_{\text{BA}}) + ((T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl}) \times (\frac{P_f}{1 - P_f}) + (T_{Proc} + \frac{P_{size}}{B_w} + L_w) \times N_{hop} + T_{\text{tunnel}}) \times N_{MNN} \quad (21)$$

4.3.2 Total Cost of NEMO BS

Following is the total cost of NEMO BS by applying equation (6) and (17)

$$TC_{\text{NEMO}} = T_{\text{NEMO}} + P_c(\text{NEMO})$$

$$TC_{\text{NEMO}} = T_{\text{scan}} + T_{\text{aaa}} + T_{\text{re-ass}} + T_{\text{CONF}} + T_{\text{DAD}} + T_{\text{RS}} + T_{\text{RA}} + N_{MNN} \times (T_{\text{BU}} + T_{\text{BA}}) + ((T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl}) \times (\frac{P_f}{1 - P_f}) + (T_{Proc} + \frac{P_{size}}{B_w} + L_w) \times N_{hop} + T_{\text{tunnel}}) \times N_{MNN} \quad (22)$$

4.3.3 Total Cost of PMIPv6 with NEMOBS

Following is the total cost of NEMO + PMIPv6 by applying equation (8) and (19)

$$TC_{\text{NEMO+PMIPv6}} = T_{\text{NEMO+PMIPv6}} + P_c(\text{NEMO} + \text{PMIPv6})$$

$$TC_{\text{NEMO+PMIPv6}} = T_{\text{scan}} + T_{\text{aaa}} + T_{\text{re-ass}} + T_{\text{RS}} + T_{\text{RA}} + T_{\text{CONF}} + N_{MNN} \times (T_{\text{BU}} + T_{\text{BA}}) + (T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl}) \times (\frac{P_f}{1 - P_f}) + ((T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl}) \times (\frac{P_f}{1 - P_f}) + ((T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl}) \times (\frac{P_f}{1 - P_f}) + (T_{Proc} + \frac{P_{size}}{B_w} + L_w) \times N_{hop} + T_{\text{tunnel}}) \times N_{MNN} \quad (23)$$

4.3.4 Total Cost of EFNEMO

Following is the total cost of NEMO + FMIPv6 by applying equation (7) and (18)

$$TC_{EFNEMO} = T_{EFNEMO} + P_c(EFNEMO)$$

$$TC_{EFNEMO} = T_{scan} + T_{aaa} + T_{re-ass} + T_{CONF} + T_{new} + T_{Fast} + T_{DAD} + 2T_{RS} + N_{MNN} \times (T_{BU} + T_{BA}) +$$

$$N_{MNN} \left(N_{hop} \left(L_w + T_{Proc} + \frac{P_{size}}{B_w} \right) + \frac{4P_f(L_{wl} + T_{Proc} + \frac{P_{size}}{B_{wl}})}{1 - P_f} + T_{tunnel} \right) \quad (24)$$

4.3.5 Total Cost of Proposed BUNSD-LMA

Following is the total cost of BUNSD-LMA by applying equation (9) and (20)

$$TC_{BUNSD-LMA} = T_{BUNSD-LMA} + P_c(BUNSD-LMA)$$

$$T_{BUNSD-LMA} = T_{scan} + T_{aaa} + T_{re-ass} + T_{RS} + T_{RA} + T_{CONF} + T_{EBU} + \left(T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl} \right) \times \left(\frac{P_f}{1 - P_f} \right) + \left(T_{Proc} + \frac{P_{size}}{B_{wl}} + L_{wl} \right) \times \left(\frac{P_f}{1 - P_f} \right) + \left(T_{Proc} + \frac{P_{size}}{B_{wl}} + L_w \right) \times N_{hop} + T_{tunnel} \times N_{MNN} \quad (25)$$

5. Numerical Analysis Result

Thus, we analyse the numerical result for PMIPv6, NEMO BS, PMIPv6 with NEMO BS and BUNSD-LMA in term of total packet cost and handover latency. Parameters values used in this study are described in table I.

TABLE I. PARAMETERS AND VALUES

Symbols	Value
N_{MNN}	50-200
N_{hop}	1
N_{wl}	3
B_l	100Mbps
B_{wl}	11Mbps
L_w	2 ms
L_{wl}	20ms
P_{size}	512 byte
T_{Proc}	10ms
T_{tunnel}	1ms
T_{scan}	30 ms
T_{aaa}	30ms
T_{re-ass}	30 ms
T_{CONF}	300ms
T_{DAD}	1000ms
T_{REG}	550ms
T_{RS}	1000ms
T_{RA}	1000ms

L_2	50 ms
P_{BU}	72 byte
P_{BA}	52 byte
P_{PBU}	76 byte
P_{PBA}	76 byte
P_f	0.1, 0.9

Fig.7 shows the variation of the relative router solicitation latency against P_f in PMIPv6 domain with different RS packet size. Here, P_f is varied from 0.1 to 0.9, and RS packet varies between 512, 1024 and 2048. When P_f increase the handover latency is increase. However, the change in packet size of RS did not affect hand over latency. Moreover, p_f indicates how the wireless link between the MR and the serving AR/MAG is strong. For instance, as p_f is increased, the frame error rate and frame retransmission over the wireless link are increased so that the overall performance is downgraded.

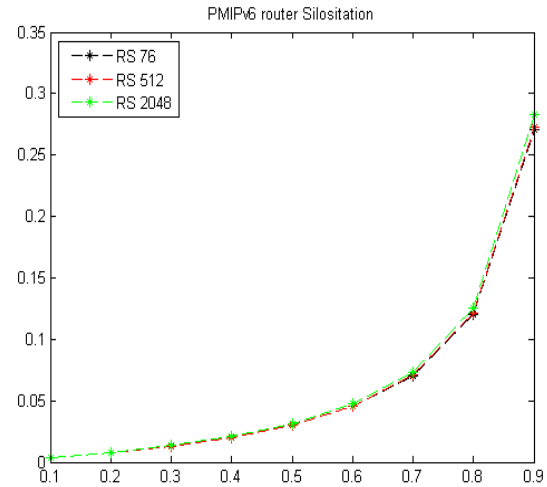


Fig. 7. Router solicitation

Fig.8 shows the variation of the relative increasing number of MNNs against handover latency in BUNSD-LMA. Here, numbers of MNNs are between 0 and 45. However, the handover latency of MNNs is remaining fixed for any increasing of number of MNNs. The values of latency time did not change because, the MR take only one signal for handover for all MNNs as one unit. Beside these, the total packet cost is increase if the number of MNNs increases. In response to these, the total cost of BUNSD-LMA is increase regarding the relative effect of packet cost in total cost of the scheme.

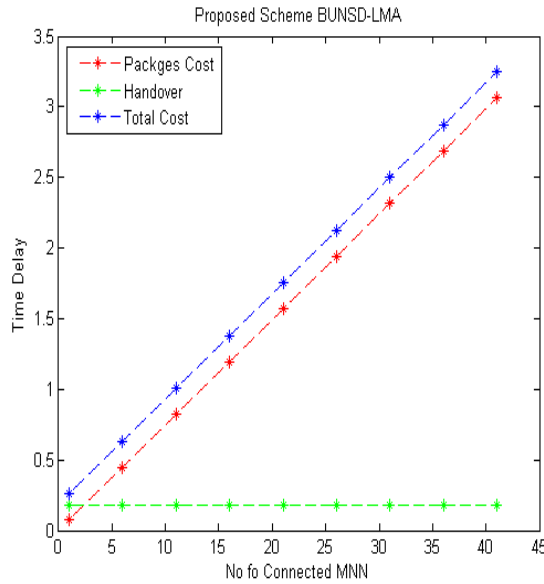


Fig. 8. Cost analysis of BUNSD-LMA

Fig.9 shows the variation of packet cost of PMIPv6, NEMO BS and BUNSD-LMA. In PMIPv6 and NEMO, the time increase due to the number of MNNs. but in BUN-LMA the latency, values did not change due to one-signal registrations of PBU in proposed scheme. This is due to advance registration of MNP in advance. In addition, the registration is done using EPBU with one signal. However, the LMA it send PBA after intercepting any message for any part of the networks. This means that the cost of the PBA does not affect the packets cost.

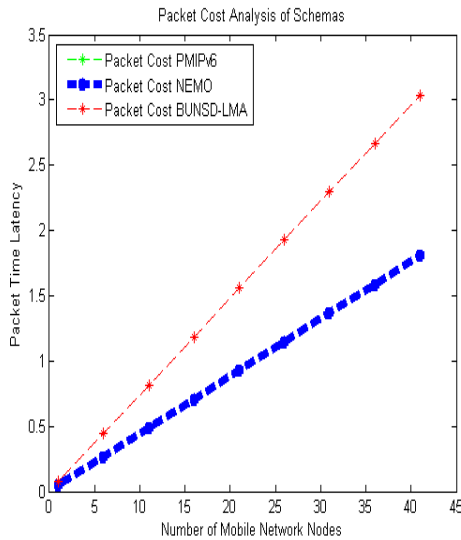


Fig. 9. Packet cost analysis of schemes

Fig.10 shows the variation of handover latency of PMIPv6, NEMO BS and BUNSD-LMA to the number of MNN. In PMIPv6 the time increases in regards to the number of MNNs increase, but in BUN-LMA the handover latency not change because, the handover perform by the mobile router in behalf of MNNs. For this, the increasing of MNN has no effect in the handover

latency. In NEMO handover latency is near to BUNSD because uses same techniques but, the degree of far distance(nested mobility) slow the performance.

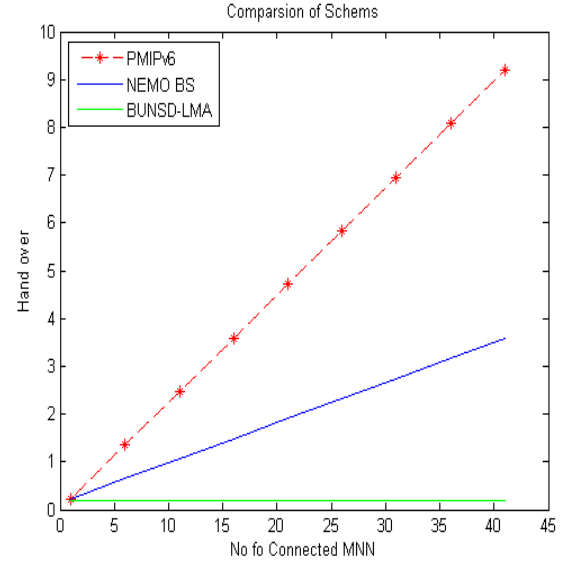


Fig. 10. Total Cost analysis of schemes

Fig. 11 shows the variation of total packet cost of PMIPv6, NEMO BS and BUNSD-LMA to the total number of MNNs. However, BUNSD-LMA outperforms PMIPv6 and NEMO BS. The total cost of packet is composed of handover latency and packet transmission delay after handover completed. Besides these, the handover is near to equal for one MNN. But, if the number of mobile network nodes increase, the total packet cost of BUNSD-LMA decrease related to the other schemes in cost ratio. We conclude that the BUNSD-LMA performs better if the numbers of MNNs increase.

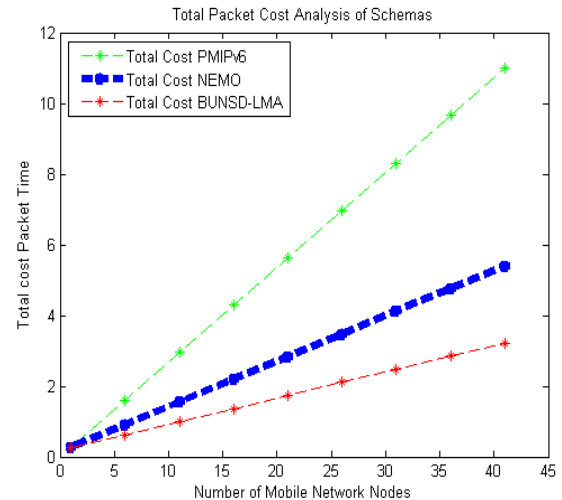


Fig. 11. Total Packets Cost analysis of schemes

Fig.12 shows the variation of total packet cost of EFNEMO, NEMO BS and BUNSD-LMA related to the total number of MNNs and handover latency. However, BUNSD-LMA outperforms EFNEMO and NEMO BS. The total cost of packet is composed of handover latency and packet transmission delay after handover completed.

Besides these, if the movement in the same domain it is perform better than movements in different proxy domain. On the other hand, the first movement of MR has slightly high signalling cost than the second movement. However, it can be notice that, when the mobile network moves away from its home network it enhance the seamless mobility of mobile network nodes.

6. Conclusion

In this work, different types of mobility management's schemas in NEMO environments are analyzed. Network model is designed and the performance cost of NEMO, EFNEMO and BUNSD-LMA are examined. The numerical results shows that the packet in BUNSD-LMA is transmitted through more optimized route with fast registration and handover latency is decreased. Besides, the total signalling cost is reduced compared with NEMO BS and EFNEMO.

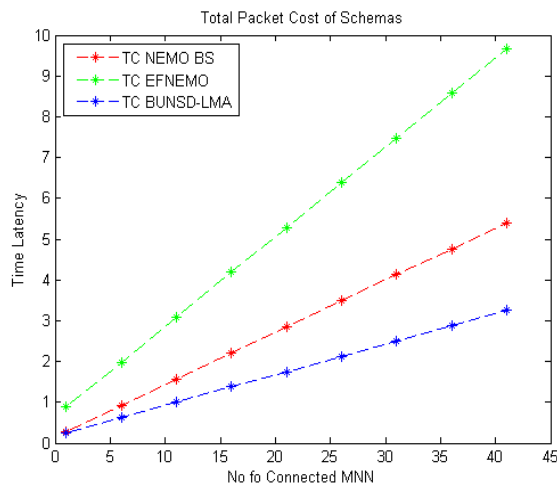


Fig. 12. Total Packets Cost analysis of schemes

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